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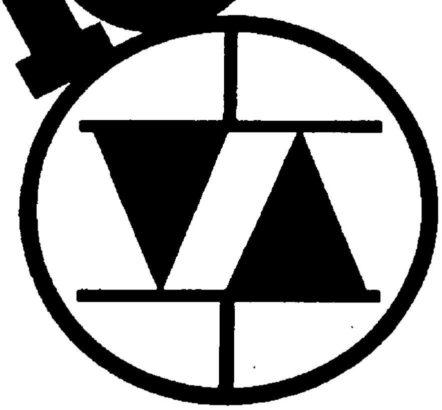
SEMI-CONDUCTOR DEVICES



A Step-by-Step Introduction

Heathkit/Zenith Educational Systems

A SPECTRUM BOOK

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Attachment 4

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These same relative changes occur in both types of diodes, even though the reverse currents are generally higher in the germanium types. For both germanium and silicon diodes, the reverse or leakage current doubles for approximately every 10° Centigrade rise in temperature.

The forward voltage drop across a conducting diode is also affected by temperature changes. This is illustrated in Figure 2-8. The forward voltage drop is inversely proportional to temperature. As the temperature rises, the voltage drop decreases. This effect is the same in both germanium and silicon devices.

Diode Symbols

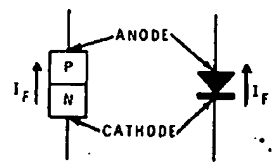

Figure 2-9 A typical Junction Diode and its Symbol.

When diodes are shown in a circuit drawing or schematic, it is convenient to represent them with an appropriate symbol. The symbol most commonly used to represent the diode is shown in Figure 2-9 along with a typical PN junction diode. Notice that the P section of the diode is represented by a triangle (also called an arrow) and the N section is represented by a bar (also called a rectangle). The arrows that are placed beside the diode and its symbol indicate the direction of forward current (I_F) or electron flow. As you discovered earlier, the forward current must flow from the N section to the P section of the diode. This means that the forward current through the symbol must flow from the bar or rectangle to the triangle or arrow. In other words forward current flow is always against the arrow in the diode symbol. Also notice that the N and P sections of the diode and the corresponding portions of the diode symbol have been identified as the *cathode* and the *anode* respectively. These two terms were once widely used to identify the two principle elements within a vacuum tube diode. However, they are now commonly used to describe the two sections of a junction diode. The cathode (N-type) is simply the section of the diode that supplies the electrons and the anode (P-type) is the section that collects the electrons.

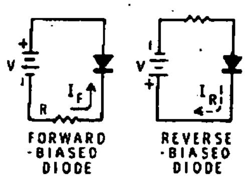

Figure 2-10
Forward and Reverse-biased diode circuits

Figure 2-10 shows how forward-biased and reverse-biased diodes are represented in schematic form. Notice that when the negative and positive terminals of the battery are connected to the cathode and anode of the diode respectively, the diode is forward-biased and will conduct a relatively high forward current. (I_F). The resistor is added in series with the diode as shown to limit this forward current to a safe value. Also notice that when the battery terminals are reversed, the diode is reverse-biased and only a very low reverse current (I_R) will flow through the device.

IMPATT Diodes

The IMPATT (impact avalanche transit time) diode is specially designed to operate within its reverse breakdown region but unlike the zener diode previously described, this device is not used to provide voltage regulation. Instead, the device can be made to generate rf power when used in conjunction with other components. The rf signals generated by this diode are extremely high (5000 to 6000 Megahertz and higher) and are produced because of the negative resistance exhibited by the device when it is operating in its breakdown region.

The IMPATT diode provides a means of generating extremely high frequencies with a minimum number of components. The device needs only a tuned resonant circuit and the proper dc operating voltage. Typical IMPATT diode oscillator circuits are capable of generating several watts of rf power at frequencies as high as 10 Gigahertz (10,000 Megahertz) at an efficiency of approximately 10%. Although the efficiency (ratio of power output to power input) may seem low, these devices represent one of the most efficient means of generating frequencies in the microwave band.

IMPATT diodes are extremely small in size (often less than ⅛ of an inch long) and are packaged in a manner similar to the varactor diodes previously discussed. Several IMPATT diodes are shown in Figure 4-11. Notice that these diodes are mounted in packages which can either be imbedded in or screwed into a resonant metal cavity that acts as a tuned circuit at microwave frequencies. Also, each package case serves as a heat conducting medium to allow heat to flow away from the tiny PN junction inside of each device.

Figure 4-11
Typical IMPATT diodes designed for use in the microwave range.
(Courtesy of Hewlett Packard)

Hot Carrier Diodes

The hot carrier diode (HCD) is formed by placing an N-type semiconductor material (usually silicon) in contact with a metal such as gold, silver or aluminum to form a metal-to-semiconductor junction. This diode operates in a manner similar to ordinary PN junction diodes but there are several important differences. The barrier voltage developed within the device is approximately one half as great as the barrier voltage within an ordinary silicon diode. This means that the forward

voltage drop across the diode is approximately 0.3 volts instead of 0.6 or 0.7 volts. Also, the HCD operates with majority carriers (electrons); virtually no minority carriers are involved. This means that the reverse or leakage current through the device is extremely small. Figure 4-12 shows the basic HCD diode construction and the symbol normally used to represent it.

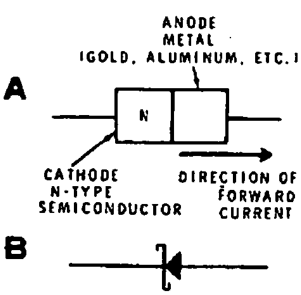

Figure 4-12 A hot carrier diode and its schematic symbol

The term hot carrier diode is used because the electrons move from the N-type semiconductor material cathode across the junction to the metallic anode (the forward-biased direction of current flow) in a manner similar to the movement of electrons through a vacuum tube diode. In other words the electrons possess a high level of kinetic energy just like the electrons leaving the heated cathode of a vacuum tube.

The barrier voltage produced within the HCD is often referred to as the Schottky-barrier because the German scientist Schottky discovered the operating principle of the device in 1938. For this reason the HCD is also commonly referred to as a Schottky-barrier diode or simply a Schottky-diode.

The HCD is able to change operating states (turn on and off) much faster than ordinary PN junction diodes, and it is used extensively to process high frequency ac signals. This device finds extensive use in microwave electronic mixers (circuits which combine ac signals), detectors (circuits which use rectification as a means of extracting information from ac signals), and high speed digital logic circuits. Figure 4-13 shows some typical hot carrier diodes for use in microwave circuits.

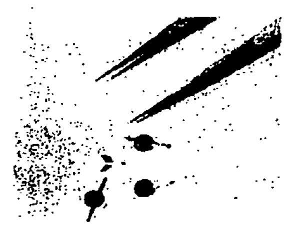

Figure 4-13 Typical hot carrier (Schottky barrier) diode packages (Courtesy of Hewlett Packard)

Gunn-Effect Diodes

Gunn-effect diodes are used like the IMPATT diodes previously described to generate rf signals in the microwave range. These devices are capable of producing oscillations when used in conjunction with a resonant circuit and a dc operating voltage. Gunn-effect diodes are often made from N-type gallium arsenide semiconductor crystals and do not have a PN junction like ordinary semiconductor diodes. However, these devices still produce a negative resistance characteristic within their bulk semiconductor materials.

Although the Gunn-effect diode does not have a PN junction and is therefore not a true diode, the device is usually designed to be biased in a specific direction. In many cases if these devices are biased in the opposite directon they will be damaged. Gunn-effect diodes are often packaged like the IMPATT diodes previously described.